

Transportation Demand Module

The NEMS Transportation Demand Module estimates energy consumption across the nine Census Divisions (see Figure 5) and over ten fuel types. Each fuel type is modeled according to fuel-specific technology attributes applicable by transportation mode. Total transportation energy consumption is the sum of energy use in eight transport modes: light-duty vehicles (cars and light trucks), commercial light trucks (8,501-10,000 lbs gross vehicle weight), freight trucks (>10,000 lbs gross vehicle weight), buses, freight and passenger aircraft, freight and passenger rail, freight shipping, and miscellaneous transport such as recreational boating. Light-duty vehicle fuel consumption is further subdivided into personal usage and commercial fleet consumption.

Key Assumptions

Light-Duty Vehicle Assumptions

The light-duty vehicle Manufacturers Technology Choice Model (MTCM) includes 63 fuel saving technologies with data specific to cars and light trucks (Tables 7.1 and 7.2) including incremental fuel economy improvement, incremental cost, first year of introduction, and fractional horsepower change.

The vehicle sales share module holds the share of vehicle sales by manufacturers constant within a vehicle size class at 2007 levels based on National Highway Traffic and Safety Administration data. [1] EPA size class sales shares are projected as a function of income per capita, fuel prices, and average predicted vehicle prices based on endogenous calculations within the MTCM. [2]

The MTCM utilizes 63 new technologies for each size class and manufacturer based on the cost-effectiveness of each technology and an initial availability year. The discounted stream of fuel savings is compared to the marginal cost of each technology. The fuel economy module assumes the following:

- The economic effectiveness of all fuel technologies are evaluated on the basis of a 3-year payback period using a real discount rate of 15 percent.
- Fuel economy standards reflect current law through model year 2011. For model years 2012 through 2016, fuel economy standards reflect NHTSA and EPA's proposed standards. For model years 2017 through 2020, the standards reflect EIA assumed increases that ensure a light vehicle combined fuel economy of 35 mpg is achieved by model 2020. For model years 2021 through 2030, fuel economy standards are held constant at model year 2020 levels with fuel economy improvements still possible based on an economic cost benefit analysis only.
- Expected future fuel prices are calculated based on an extrapolation of the growth rate between a five year moving average of fuel price 3 years and 4 years prior to the present year. This assumption is founded upon an assumed lead time of 3 to 4 years to significantly modify the vehicles offered by a manufacturer.

Table 7.1. Standard Technology Matrix For Cars¹

	Fractional Fuel Efficiency Change	Incremental Cost (1990\$)	Incremental Cost (\$/Unit Wt.)	Incremental Weight (Lbs.)	Incremental Weight (Lbs./Unit Wt.)	Introduction Year	Fractional Horse- power Change
Unit Body Construction	4	100	0	0	-6	1980	0
Material Substitution II	3.3	0	0.4	0	-5	1990	0
Material Substitution III	6.6	0	0.6	0	-10	1998	0
Material Substitution IV	9.9	0	0.9	0	-15	2006	0
Material Substitution V	13.2	0	1.2	0	-20	2014	0
Drag Reduction II	1.5	16	0	0	0	1988	0
Drag Reduction III	3.0	32	0	0	0.2	1992	0
Drag Reduction IV	4.2	45	0	0	0.5	2000	0
Drag Reduction V	5.0	53.5	0	0	1	2010	0
Roll-Over Technology	-1.5	100	0	0	2.2	2004	0
Side Impact Technology	-1.5	100	0	0	2.2	2004	0
Adv Low Loss Torque Converter	2	25	0	0	0	1999	0
Early Torque Converter Lockup	0.5	25.6	0	0	0	2002	0
Aggressive Shift Logic	1.5	30.5	0	0	0	1999	0
4-Speed Automatic	4.5	285	0	10	0	1980	0
5-Speed Automatic	2.5	106.5	0	20	0	1995	0
6-Speed Automatic	2.9	259	0	30	0	2003	0
6-Speed Manual	0.5	91.4	0	20	0	1995	0
CVT	5.0	240.5	0	-25	0	1998	0
Automated Manual Trans	7.3	138.6	0	0	0	2004	0
Roller Cam	2	16	0	0	0	1980	0
OHC/AdvOHV-4 Cylinder	2.0	99	0	0	0	1980	2.5
OHC/AdvOHV-6 Cylinder	2.0	115.7	0	0	0	1987	2.5
OHC/AdvOHV-8 Cylinder	2.0	132.3	0	0	0	1986	2.5
4-Valve/4-Cylinder	8	205	0	10	0	1988	4.25
4-Valve/6-Cylinder	8	280	0	15	0	1992	4.25
4 Valve/8-Cylinder	8	320	0	20	0	1994	4.25
5 Valve/6-Cylinder	8	300	0	18	0	1998	5
VVT-4 Cylinder	2.0	48.9	0	10	0	1994	1.25
VVT-6 Cylinder	2.0	97.8	0	20	0	1993	1.25
VVT-8 Cylinder	2.0	97.8	0	20	0	1993	1.25
VVL-4 Cylinder	2.0	162.2	0	25	0	1997	2.5
VVL-6 Cylinder	2.0	245.9	0	40	0	2000	2.5
VVL-8 Cylinder	2.0	317.5	0	50	0	2000	2.5
Camless Valve Actuation-4cyl	13.6	400.9	0	35	0	2020	3.25
Camless Valve Actuation-6cyl	13.6	561.3	0	55	0	2020	3.25
Camless Valve Actuation-8cyl	13.6	721.6	0	75	0	2020	3.25
Cylinder Deactivation	5.3	152.3	0	10	0	2004	0
Turbocharging/Supercharging	6.3	324.7	0	-100	0	1980	3.75
Engine Friction Reduction I	2.3	54	0	0	0	1992	0.75
Engine Friction Reduction II	2.8	60.9	0	0	0	2000	1.25
Engine Friction Reduction III	4.0	138.7	0	0	0	2008	1.75
Engine Friction Reduction IV	6.5	177	0	0	0	2016	2.25
Stoichiometric GDI/4-Cylinder	2.4	293.8	0	20	0	2006	2.5
Stoichiometric GDI/6-Cylinder	2.4	377.6	0	30	0	2006	2.5
Lean Burn GDI	10.0	640.5	0	20	0	2020	0
5W-30 Engine Oil	0.5	4.0	0	0	0	1998	0
5W-20 Engine Oil	2	16.7	0	0	0	2003	0
OW-20 Engine Oil	3.1	150	0	0	0	2030	0
Electric Power Steering	1.5	90.6	0	0	0	2004	0
Improved Alternator	0.3	15	0	0	0	2005	0
Improved Oil/Water Pump	0.5	10	0	0	0	2000	0
Electric Oil/Water Pump	1	93.4	0	0	0	2007	0
Tires II	1.8	15.8	0	-8	0	1995	0
Tires III	2.7	19.9	0	-12	0	2005	0
Tires IV	3.8	22.9	0	-16	0	2015	0
Front Wheel Drive	6	250	0	0	-6	1980	0
Four Wheel Drive Improvements	1.3	93.8	0	0	-1	2000	0
42V-Launch Assist and Regen	7.5	280	0	80	0	2005	-2.5
42V-Engine Off at Idle	6.8	496.6	0	45	0	2005	0
Tier 2 Emissions Technology	-1	120	0	20	0	2006	0
Increased Size/Weight	-0.5	0	0	0	2.55	2006	0
Variable Compression Ratio	4	350	0	25	0	2015	0

¹ Fractional changes refer to the percentage change from the 1990 values.

Sources: Energy and Environment Analysis, *Documentation of Technology included in the NEMS Fuel Economy Model for Passenger Cars and Light Trucks* (September, 2002). National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards* (Copyright 2002).

National Highway Traffic Safety Administration, *Corporate Average Fuel Economy for MY 2011-2015 Passenger Cars and Light Trucks* (April 2008). U.S.

Environmental Protection Agency, *Interim Report: New Powertrain Technologies and Their Projected Costs* (October 2005)

Table 7.2. Standard Technology Matrix For Light Trucks¹

	Fractional Fuel Efficiency Change	Incremental Cost (1990\$)	Incremental Cost (\$/UnitWt.)	Incremental Weight (Lbs.)	Incremental Weight (Lbs./UnitWt.)	Introduction Year	Fractional Horse- power Change
Unit Body Construction	4	100	0	0	-6	1980	0
Material Substitution II	3.3	0	0.4	0	-5	1994	0
Material Substitution III	6.6	0	0.6	0	-10	2002	0
Material Substitution IV	9.9	0	0.9	0	-15	2010	0
Material Substitution V	13.2	0	1.2	0	-20	2018	0
Drag Reduction II	2.0	32	0	0	0	1992	0
Drag Reduction III	4.1	57	0	0	0.2	1998	0
Drag Reduction IV	6.4	89	0	0	0.5	2006	0
Drag Reduction V	7.8	109	0	0	1	2014	0
Roll-Over Technology	-1.5	100	0	0	2.2	2006	0
Side Impact Technology	-1.5	100	0	0	2.2	2006	0
Adv Low Loss Torque Converter	2	25	0	0	0	2005	0
Early Torque Converter Lockup	0.5	25.6	0	0	0	2003	0
Aggressive Shift Logic	1.5	30.5	0	0	0	1999	0
4-Speed Automatic	4.5	285	0	10	0	1980	0
5-Speed Automatic	2.5	106.5	0	20	0	1995	0
6-Speed Automatic	2.9	259	0	30	0	2003	0
6-Speed Manual	0.5	91.4	0	20	0	1995	0
CVT	7.0	138.6	0	-25	0	1998	0
Automated Manual Trans	3.4	157.5	0	0	0	2004	0
Roller Cam	2	16	0	0	0	1985	0
OHC/AdvOHV-4 Cylinder	2.0	99	0	0	0	1980	2.5
OHC/AdvOHV-6 Cylinder	2.0	115.7	0	0	0	1990	2.5
OHC/AdvOHV-8 Cylinder	2.0	132.3	0	0	0	1990	2.5
4-Valve/4-Cylinder	7	205	0	10	0	1998	4.25
4-Valve/6-Cylinder	7	280	0	15	0	2000	4.25
4 Valve/8-Cylinder	7	320	0	20	0	2000	4.25
5 Valve/6-Cylinder	7	300	0	18	0	2010	5
VVT-4 Cylinder	2.0	48.9	0	10	0	1998	1.25
VVT-6 Cylinder	2.0	97.8	0	20	0	1997	1.25
VVT-8 Cylinder	2.0	97.8	0	20	0	1997	1.25
VVL-4 Cylinder	2.0	161.2	0	25	0	2002	2.5
VVL-6 Cylinder	2.0	245.4	0	40	0	2001	2.5
VVL-8 Cylinder	2.0	317.5	0	50	0	2006	2.5
Camless Valve Actuation-4cyl	13.6	400.9	0	35	0	2020	3.25
Camless Valve Actuation-6cyl	13.6	561.3	0	55	0	2020	3.25
Camless Valve Actuation-8cyl	13.6	721.6	0	75	0	2020	3.25
Cylinder Deactivation	5.3	152.3	0	10	0	2004	0
Turbocharging/Supercharging	6.3	481.3	0	-100	0	1987	3.75
Engine Friction Reduction I	2.5	25	0	0	0	1992	0.75
Engine Friction Reduction II	3.5	63	0	0	0	2000	1.25
Engine Friction Reduction III	5	178.0	0	0	0	2010	1.75
Engine Friction Reduction IV	6.5	177	0	0	0	2016	2.25
Stoichiometric GDI/4-Cylinder	2.4	293.9	0	20	0	2008	2.5
Stoichiometric GDI/6-Cylinder	2.4	377.7	0	30	0	2010	2.5
Lean Burn GDI	10.8	640.5	0	20	0	2010	0
5W-30 Engine Oil	0.5	4.0	0	0	0	1998	0
5W-20 Engine Oil	2	16.7	0	0	0	2003	0
OW-20 Engine Oil	3.1	150	0	0	0	2030	0
Electric Power Steering	1.8	90.2	0	0	0	2005	0
Improved Alternator	1.5	15	0	0	0	2005	0
Improved Oil/Water Pump	0.5	10	0	0	0	2000	0
Electric Oil/Water Pump	1	93.4	0	0	0	2008	0
Tires II	0.0	30	0	-8	0	1995	0
Tires III	1.3	15.4	0	-12	0	2005	0
Tires IV	2.7	19.5	0	-16	0	2015	0
Front Wheel Drive	2	250	0	0	-3	1984	0
Four Wheel Drive Improvements	1.3	93.8	0	0	-1	2000	0
42V-Launch Assist and Regen	7.5	280	0	80	0	2005	2.5
42V-Engine Off at Idle	6.8	434.9	0	45	0	2005	0
Tier 2 Emissions Technology	-1	160	0	20	0	2006	0
Increased Size/Weight	0.8	0	0	0	3.75	2006	0
Variable Compression Ratio	4	350	0	25	0	2015	0

¹Fractional changes refer to the percentage change from the 1990 values.

Sources: Energy and Environment Analysis, *Documentation of Technology included in the NEMS Fuel Economy Model for Passenger Cars and Light Trucks* (September, 2002). National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards* (Copyright 2002).

National Highway Traffic Safety Administration, *Corporate Average Fuel Economy for MY 2011-2015 Passenger Cars and Light Trucks* (April 2008). U.S. Environmental Protection Agency, *Interim Report: New Powertrain Technologies and Their Projected Costs* (October 2005)

Degradation factors are used to convert new vehicle tested fuel economy values to "on-road" fuel economy values (Table 7.3). The degradation factors represent adjustments made to tested fuel economy values to account for the difference experienced between fuel economy performance realized in the CAFE test procedure compared fuel economy realized under normal driving conditions.

Table 7.3. Car and Light Truck Degradation Factors

	2005	2010	2015	2020	2030	2035
Cars	78.3	81.8	82.3	82.8	83.8	83.8
Light Trucks	85.9	84.0	84.0	84.0	84.0	84.0

Source: Energy Information Administration, *Transportation Sector Model of the National Energy Modeling System, Model Documentation 2007*, DOE/EIA-M070(2007), (Washington, DC, 2007).

Commercial Light Duty Fleet Assumptions

The Transportation Demand Module is designed to divide commercial light-duty fleets into three types: business, government, and utility. Based on this classification, commercial light-duty fleet vehicles vary in survival rates and duration in fleet use before being sold for use as personal vehicles (Table 7.4). The average length of time vehicles are kept before being sold for personal use is 4 years for business use, 5 years for government use, and 6 years for utility use. Of total automobile sales to fleets, 80.6 percent are used in business fleets, 6.5 percent in government fleets, and 12.9 percent in utility fleets. Of total light truck sales to fleets, 59.5 percent are used in business fleets, 3.6 percent in government fleets, and 36.8 percent in utility fleets. [3] Both the automobile and light truck shares by fleet type are held constant from 2004 through 2035. In 2006, 18.1 percent of all automobiles sold and 18.2 percent of all light trucks sold were for fleet use. The share of total automobile and light truck sales to decline over the forecast period based on historic trends.

Table 7.4. 2005 Percent of fleet Alternative Fuel Vehicles by Fleet Type by Size class

	Mini	Subcompact	Compact	Midsized	Large	2-Seater
Car						
Business	0.00	10.52	10.73	42.68	36.07	0.00
Government	0.00	2.80	39.98	2.84	54.39	0.00
Utility	0.00	7.86	34.74	12.32	45.08	0.00
	SM Pk	LG Pk	SM Van	LG Van	SM Util	LG Util
Light Truck						
Business	7.94	35.14	7.89	26.76	5.46	16.81
Government	6.75	50.81	28.41	4.60	1.62	7.81
Utility	8.22	52.06	5.99	32.69	0.32	0.72

Source: CNEAF Alternatives to Traditional Transportation Fuels 2005 (Part II - User and Fuel Data). http://www.eia.doe.gov/cneaf/alternate/page/aftables/afvtransfuel_II.html #in use

Alternative-fuel shares of fleet vehicle sales by fleet type are held constant at year 2005 levels. Size class sales shares of vehicles are held constant at 2005 levels (Table 7.5). [4] Individual sales shares of new vehicles purchased by technology type are assumed to remain constant for utility, government, and for business fleets [5] (Table 7.6).

Annual VMT per vehicle by fleet type stays constant over the forecast period based on the Oak Ridge National Laboratory fleet data.

Fleet fuel economy for both conventional and alternative-fuel vehicles is assumed to be the same as the personal new vehicle fuel economy and is subdivided into six EPA size classes for cars and light trucks.

Table 7.5. Commercial Fleet Size Class Shares by Fleet and Vehicle Type
(Percentage)

Fleet Type by Size Class	Automobiles	Light Trucks
Business Fleet		
Mini	3.12	2.46
Subcompact	23.42	8.41
Compact	26.62	23.26
Midsized	36.15	8.12
Large	9.90	14.15
2-seater	0.78	43.60
Government Fleet		
Mini	0.19	6.67
Subcompact	4.58	43.60
Compact	20.55	10.44
Midsized	28.64	17.10
Large	45.99	3.82
2-seater	0.05	18.37
Utility Fleet		
Mini	1.50	7.26
Subcompact	12.47	38.71
Compact	10.01	11.79
Midsized	59.23	18.91
Large	16.42	7.19
2-seater	0.38	16.15

Source: Oak Ridge National Laboratory, *Fleet Characteristics and Data Issues*, Stacy Davis and Lorena Truett, final report prepared for the Department of Energy, Energy Information Administration, Office of Integrated Analysis and Forecasting, (Oak Ridge, TN, January 2003).

Table 7.6. Share of New Vehicle Purchases by Fleet Type and Technology Type
(Percentage)

Technology	Business	Government	Utility
Cars			
Gasoline	99.59	79.40	99.72
Ethanol Flex	0.27	18.98	0.13
Methanol Flex	0.00	0.00	0.00
Electric	0.01	0.01	0.00
CNG Bi-Fuel	0.05	1.38	0.10
LPG Bi-Fuel	0.01	0.00	0.00
CNG	0.07	0.22	0.05
LPG	0.00	0.00	0.00
Light Trucks			
Gasoline	96.07	68.97	99.69
Ethanol Flex	3.38	28.03	0.11
Methanol Flex	0.00	0.00	0.00
Electric	0.01	0.00	0.00
CNG Bi-Fuel	0.32	2.57	0.14
LPG Bi-Fuel	0.00	0.01	0.01
CNG	0.22	0.42	0.04
LPG	0.00	0.00	0.01

Sources: CNEAF Alternatives to Traditional Transportation Fuels 2005 (part II - User and Fuel Data).
http://www.eia.doe.gov/cneaf/alternate/page/aftables/afvtransfuel_II.html#in use.

The Light Commercial Truck Model

The Light Commercial Truck Module of the NEMS Transportation Model represents light trucks that have a 8,501 to 10,000 pound gross vehicle weight rating (Class 2B vehicles). These vehicles are assumed to be used primarily for commercial purposes.

The module implements a twenty-year stock model that estimates vehicle stocks, travel, fuel economy, and energy use by vintage. Historic vehicle sales and stock data, which constitute the baseline from which the forecast is made, are taken from a recent Oak Ridge National Laboratory study. [6] The distribution of vehicles by vintage, and vehicle scrappage rates are derived from R.L. Polk company registration data. [7],[8] Vehicle travel by vintage was constructed using vintage distribution curves and estimates of average annual travel by vehicle. [9],[10]

The growth in light commercial truck VMT is a function of industrial output for agriculture, mining, construction, trade, utilities, and personal travel. These industrial groupings were chosen for their correspondence with output measures being forecast by NEMS. The overall growth in VMT reflects a weighted average based upon the distribution to total light commercial truck VMT by sector. Forecasted fuel efficiencies are assumed to increase at the same annual growth rate as conventional gasoline light-duty trucks (<8,500 pounds gross vehicle weight).

Consumer Vehicle Choice Assumptions

The Consumer Vehicle Choice Module (CVCM) utilizes a nested multinomial logit (NMNL) model that predicts sales shares based on relevant vehicle and fuel attributes. The nesting structure first predicts the probability of fuel choice for multi-fuel vehicles within a technology set. The second level nesting predicts penetration among similar technologies within a technology set (i.e., gasoline versus diesel hybrids). The third level choice determines market share among the different technology sets. [11] The technology sets include:

- Conventional fuel capable (gasoline, diesel, bi-fuel and flex-fuel),
- Hybrid (gasoline and diesel),
- Plug in hybrid (10 mile all electric range and 40 mile all electric range)
- Dedicated alternative fuel (CNG, LPG, methanol, and ethanol),
- Fuel cell (gasoline, methanol, and hydrogen), and
- electric battery powered (nickel-metal hydride and lithium ion) [12]

The vehicle attributes considered in the choice algorithm include: price, maintenance cost, battery replacement cost, range, multi-fuel capability, home refueling capability, fuel economy, acceleration and luggage space. With the exception of maintenance cost, battery replacement cost, and luggage space, vehicle attributes are determined endogenously. [13] Battery costs for plug-in hybrid electric and all-electric vehicles are based on a production based function over several technology phase periods. The fuel attributes used in market share estimation include availability and price. Vehicle attributes vary by six EPA size classes for cars and light trucks and fuel availability varies by Census division. The NMNL model coefficients were developed to reflect purchase decisions for cars and light trucks separately.

Where applicable, CVCM fuel efficient technology attributes are calculated relative to conventional gasoline miles per gallon. It is assumed that many fuel efficiency improvements in conventional vehicles will be transferred to alternative-fuel vehicles. Specific individual alternative-fuel technological improvements are also dependent upon the CVCM technology type, cost, research and development, and availability over time. Make and model availability estimates are assumed according to a logistic curve based on the initial technology introduction date and current offerings. Coefficients summarizing consumer valuation of vehicle attributes were derived from assumed economic valuation compared to vehicle price elasticities. Initial CVCM vehicle stocks are set according to EIA surveys. [14] A fuel switching algorithm based on the relative fuel prices for alternative fuels compared to gasoline is used to determine the percentage of total VMT represented by alternative fuels in bi-fuel and flex-fuel alcohol vehicles.

Freight Truck Assumptions

The freight truck module estimates vehicle stocks, travel, fuel efficiency, and energy use of three size classes: light medium (Class 3), heavy medium (Classes 4 -6), and heavy (Classes 7-8). Within the size classes, the stock model structure is designed to cover 38 vehicle vintages and to estimate energy use by four fuel types: diesel, gasoline, LPG, and CNG. Fuel consumption estimates are reported regionally (by Census Division) according to the distillate fuel shares from the State Energy Data Report [15]. The technology input data specific to the different types of trucks including the year of introduction, incremental fuel efficiency improvement, and capital cost of introducing the new technologies, are shown in Table 7.7.

Table 7.7. Standard Technology Matrix for Freight Trucks

Technology Type	Medium Light Trucks			Medium Heavy Trucks			Heavy Trucks		
	Introd- uction Year	Capital Cost	Incr. Fuel Econ. Improve- ment	Introd- uction Year	Capital Cost	Incr. Fuel Econ. Improve- ment	Introd- uction Year	Capital Cost	Incr. Fuel Econ. Improve- ment
Aero dynamic I: Cab top deflector, sloping hood and cab side flares	2002	600.00	0.023	1995	750.00	0.023	1995	750.00	0.018
Closing/covering of gap between tractor and trailer, aero dynamic bumper, underside air baffles, wheel well covers	N/A	N/A	0.000	2004	800.00	0.036	2005	1500.00	0.023
Trailer leading and trailing edge curvatures	N/A	N/A	0.000	2005	400.00	0.009	2005	500.00	0.012
Aero Dynamics IV: pneumatic blowing	N/A	N/A	0.000	N/A	N/A	0.000	2010	2500.00	0.045
Tires I: radials	1995	40.00	0.018	1995	180.00	0.018	1995	300.00	0.014
Tires II: low rolling resistance	2004	180.00	0.023	2005	280.00	0.023	2005	550.00	0.027
Tires III: super singles	N/A	N/A	0.000	N/A	N/A	0.000	2005	700.00	0.018
Tires IV: reduced rolling resistance from pneumatic blowing	N/A	N/A	0.000	N/A	N/A	0.000	2015	500.00	0.011
Transmission: lock-up, electronic controls, reduced friction	2005	750.00	0.018	2005	900.00	0.018	2005	1000.00	0.018
Diesel Engine I: turbocharged, direct injection with better thermal management	2003	700.00	0.045	2004	1000.00	0.072	N/A	N/A	0.000
Diesel Engine II: integrated starter/alternator with idle off and limited regenerative braking	2005	1500.00	0.045	2005	1200.00	0.045	N/A	N/A	0.000
Diesel Engine III: improved engine iwth lower friction, better injectors, and efficient combustion	2012	2000.00	0.090	2008	2000.00	0.072	N/A	300.00	0.000
Diesel Engine IV: hybrid electric powertrain	2010	6000.00	0.360	2010	8000.00	0.360	N/A	N/A	0.000
Diesel Engine V: internal friction reduction - iimproved lubricants and bearings	N/A	N/A	0.000	N/A	N/A	0.000	2005	500.00	0.018
Diesel Engine VI: increased peak cylinder pressure	N/A	NA	0.000	N/A	N/A	0.000	2006	1000.00	0.036
Diesel Engine VII: improved injectors and more efficient combustion	N/A	N/A	0.000	N/A	N/A	0.000	2007	1500	0.054
Diesel Engine VIII: reduce waste heat improved thermal management	N/A	N/A	0.000	N/A	N/A	0.000	2010	2000	0.090

Table 7.7. Standard Technology Matrix for Freight Trucks (cont.)

Technology Type	Medium Light Trucks			Medium Heavy Trucks			Heavy Trucks		
	Introd- uction Year	Capital Cost	Incr. Fuel Econ. Improve- ment	Introd- uction Year	Capital Cost	Incr. Fuel Econ. Improve- ment	Introd- uction Year	Capital Cost	Incr. Fuel Econ. Improve- ment
Gasoline Engine I: electronic fuel injection, DOHC, multiple valves	2003	700.00	0.045	2003	1000.00	0.045	N/A	N/A	0.000
Gasoline Engine II: integrated starter/alternator with idle off and limited regenerative braking	2005	1000.00	0.045	2005	1200.00	0.072	N/A	N/A	0.000
Gasoline Engine III: direct injection (GDI)	2008	700.00	0.108	2008	1000.00	0.108	N/A	N/A	0.000
Gasoline Engine IV: hybrid electric powertrain	2010	6000.00	0.405	2010	8000.00	0.405	N/A	N/A	0.000
Weight Reduction I: high strength lightweight materials	2010	1300.00	0.045	2007	2000.00	0.045	2005	2000.00	0.090
Diesel Emission-NO _x I: exhaust recirculation, timing retard, selective catalytic reduction	2002	250.00	-0.040	2003	400.00	-0.040	2003	500.00	-0.040
Diesel Emissions-NO _x II: nitrogen enriched combustion air	2003	500.00	-0.005	2003	700.00	-0.005	2003	750.00	-0.005
Diesel Emissions-NO _x III: non-thermal plasma catalyst	2007	1000.00	-0.015	2006	1200.00	-0.015	2007	1250.00	-0.015
Diesel Emissions-NO _x IV: NO _x absorber system	2007	1500.00	-0.030	2006	2000.00	-0.030	2007	2500.00	-0.030
Diesel Emission-PM I: oxidation catalyst	2002	150.00	-0.005	2002	200.00	-0.005	2002	250.00	-0.005
Diesel Emission-PM II: catalytic particulate filter	2006	1000.00	-0.015	2006	1250.00	-0.025	2006	1500.00	-0.015
Diesel Emission- HC/CO I: oxidation catalyst	2002	150.00	-0.005	2002	200.00	-0.005	2002	250.00	-0.005
Diesel Emission- HC/CO II: closed crankcase system	2005	50.00	0.000	2005	65.00	0.000	2005	75.00	0.000
Gasoline Emission- PM I: Improved oxidation catalyst	2005	250.00	-0.003	2005	350.00	-0.003	N/A	N/A	0.000
Gasoline Emission-NO _x I: EGR/spark retard	2002	25.00	-0.015	2002	25.00	-0.015	N/A	N/A	0.000
Gasoline Emission-NO _x II: oxygen sensors	2003	75.00	0.000	2003	75.00	0.000	N/A	N/A	0.000
Gasoline Emission-NO _x III: secondary air/closed loop system	2008	50.00	0.000	2008	50.00	0.000	N/A	N/A	0.000

Table 7.7. Standard Technology Matrix for Freight Trucks (cont.)

Technology Type	Medium Light Trucks			Medium Heavy Trucks			Heavy Trucks		
	Introd- uction Year	Capital Cost	Incr. Fuel Econ. Improve- ment	Introd- uction Year	Capital Cost	Incr. Fuel Econ. Improve- ment	Introd- uction Year	Capital Cost	Incr. Fuel Econ. Improve- ment
Gasoline Emission- HC/CO I: oxygen sensors	2003	75.00	0.000	2003	75.00	0.000	N/A	N/A	0.000
Gasoline Emission- HC/CO II: evap. canister w/improved vacuum, materials, and connectors	2003	50.00	0.000	2003	50.00	0.000	N/A	N/A	0.000
Gasoline Emission- HC/CO III: oxidation catalyst	2005	250.00	-0.003	2005	350.00	-0.003	N/A	N/A	0.000

1. Payback period is same for the three modes.

The freight module uses projections of dollars of industrial output to estimate growth in freight truck travel. The industrial output is converted to an equivalent measure of volume output using freight adjustment coefficients. [16],[17] These freight adjustment coefficients vary by North American Industrial Classification System (NAICS) code with the deviation diminishing gradually over time toward parity. Freight truck load-factors (ton-miles per truck) by NAICS code are constants formulated from historical data. [18]

Fuel economy of new freight trucks is dependent on the market penetration of various emission control technologies and advanced technology components.[19] For the advanced technology components, market penetration is determined as a function of technology type, cost effectiveness, and introduction year. Cost effectiveness is calculated as a function of fuel price, vehicle travel, fuel economy improvement, and incremental capital cost. Emissions control equipment is assumed to enter the market to meet regulated emission standards.

Heavy truck freight travel is estimated by class size and fuel type based on matching projected freight travel demand (measured by industrial output) to the travel supplied by the current fleet. Travel by vintage and size class is then adjusted so that total travel meets total demand. Initial heavy vehicle travel, by vintage and size class, is derived using Vehicle Inventory and Use Survey (VIUS) data. [20]

Initial freight truck stocks by vintage are obtained from R. L. Polk Co. and are distributed by fuel type using VIUS data. [21] Vehicle scrappage rates are also estimated using R. L. Polk Co. data. [22]

Freight and Transit Rail Assumptions

The freight rail module uses the industrial output by NAICS code measured in real 1987 dollars and converts these dollars into an adjusted volume equivalent. Coal production from the NEMS Coal Market Module is used to adjust coal based rail travel. Freight rail adjustment coefficients (used to convert dollars to volume equivalents) are based on historical data and remain constant.[23],[24] Initial freight rail efficiencies are based on historic data taken from the Transportation Energy Databook. [25] The distribution of rail fuel consumption by fuel type is also based on historical data and remains constant over the projection. [26] Regional freight rail consumption estimates are distributed according to the State Energy Data Report. [27]

Domestic and International Shipping Assumptions

Similar to the previous sub-module, the domestic freight shipping module uses the industrial output by NAICS code measured in real 1987 dollars and converts these dollars into an adjusted volume equivalent.

The freight adjustment coefficients (used to convert dollars to volume equivalents) are based on historical data. Domestic shipping efficiencies are based on the model developed by Argonne National Laboratory. The energy consumption in the international shipping module is a function of the total level of imports and exports. The distribution of domestic and international shipping fuel consumption by fuel type is based on

historical data and remains constant throughout the forecast. [28] Regional domestic shipping consumption estimates are distributed according to the residual oil regional shares in the *State Energy Data Report*. [29]

Air Travel Demand Assumptions

The air travel demand module calculates the domestic and international ticket prices for travel as a function of fuel cost. Domestic and international revenue passenger miles are based on historic data, [30] per capita income, and ticket price. The revenue ton miles of air freight are based on merchandise exports, gross domestic product, and fuel cost. [31]

Airport capacity constraints based on the *FAA's Airport Capacity Benchmark Report 2004* are incorporated into the air travel demand module using airport capacity measures. [32] Airport capacity is defined by the maximum number of flights per hour airports can routinely handle, the amount of time airports operate at optimal capacity, and passenger load factors. Capacity expansion is expected to be delayed due to the economic environment and fuel costs.

Aircraft Stock/Efficiency Assumptions

The aircraft stock and efficiency module consists of a world, US and Non-US, stock model of wide body, narrow body, and regional jets by vintage. Total aircraft supply for a given year is based on the initial supply of aircraft for model year 2008, new passenger sales, and the survival rate by vintage (Table 7.8). [33] New passenger sales are a function of revenue passenger miles and gross domestic product.

Table 7.8. 2008 USA Passenger and Cargo Aircraft Supply and Survival Rate

Age of Aircraft (years)						
Aircraft Type	New	1-10	11-20	21-30	>30	Total
Passenger						
Narrow Body	114	1,716	1,261	610	283	3,984
Wide Body	3	285	266	164	40	758
Regional Jets	130	1,785	115	11	10	2,051
Cargo						
Narrow Body	0	6	71	134	250	461
Wide Body	4	104	208	211	99	626
Survival Curve (fraction)	New	5	10	20	30	
Narrow Body	1.0000	0.9998	0.9992	0.9911	0.9256	
Wide Body	1.0000	0.9980	0.9954	0.9754	0.8892	
Regional Jets	1.0000	0.9967	0.9942	0.9816	0.9447	

Source: Jet Information Services, 2008 World Jet Inventory, data tables (2008).

Wide and narrow body planes over 25 years of age are placed as cargo jets according to a cargo percentage varying from 50 percent of 25 year old planes to 100 percent of those aircraft 30 years and older. The available seat-miles per plane, which measure the carrying capacity of the airplanes by aircraft type, vary over time, with wide bodies remaining constant and narrow bodies increasing. [34] The difference between seat-miles demanded and available seat-miles represents potential newly purchased aircraft. If demand is less than supply, then passenger aircraft is either parked or exported, starting with twenty nine year old aircraft, at a pre-defined rate. Aircraft continue to be parked until equilibrium is reached. If supply is less than demand planes are either imported or unparked and brought back into service.

Technological availability, economic viability, and efficiency characteristics of new aircraft are assumed to grow at a fixed rate. Fuel efficiency of new aircraft acquisitions represents an improvement over the stock efficiency of surviving airplanes. A generic set of new technologies (Table 7.9) are introduced in different years and with a set of improved efficiencies over the base year (2007). Regional shares of all types of aircraft fuel use are assumed to be constant and are consistent with the State Energy Data Report estimate of regional jet fuel shares.

Table 7.9. Standard Technology Matrix for Air Travel

Technology	Introduction Year	Fractional Efficiency Improvement	Jet Fuel Trigger Price (\$/gal)
Technology #1	2008	0.03	1.34
Technology #2	2014	0.07	1.34
Technology #3	2020	0.11	1.34
Technology #4	2025	0.15	1.34
Technology #5	2018	0.20	1.34
Technology #6	2018	0.00	1.34
Technology #7	9999	0.00	0.00
Technology #8	9999	0.00	0.00
Technology #9	9999	0.00	0.00

Source: Jet Information Services, 2008 World Jet Inventory, data tables (2008).

Legislation and Regulations

Energy Independence and Security Act of 2007 (EISA2007)

The EISA2007 legislation requires the development of fuel economy standards for work trucks (8,500 lbs. to less than 10,000 lbs GVWR) and commercial medium- and heavy-duty on-highway vehicles (10,000 lbs or more GVWR). The new fuel economy standards require consideration of vehicle attributes and duty requirements and can prescribe standards for different classes of vehicles, such as buses used in urban operation or semi-trucks used primarily in highway operation. The Act provides a minimum of 4 full model years lead time before the new fuel economy standard is adopted and 3 full model years after the new fuel economy standard has been established before the fuel economy standards for work trucks can be modified. Because these fuel economy standards are pending and NEMS does not currently model fuel economy regulation for work trucks or commercial medium- and heavy- duty vehicles, this aspect of the Act is not included in *AEO2010*.

A fuel economy credit trading program is established based on EISA2007. Currently, CAFE credits earned by manufacturers can be banked for up to 3 years and can only be applied to the fleet (car or light truck) from which the credit was earned. Starting in model year 2011 the credit trading program will allow manufacturers whose automobiles exceed the minimum fuel economy standards to earn credits that can be sold to other manufacturers whose automobiles fail to achieve the prescribed standards. The credit trading program is designed to ensure that the total oil savings associated with manufacturers that exceed the prescribed standards are preserved when credits are sold to manufacturers that fail to achieve the prescribed standards. While the credit trading program begins in 2011, EISA2007 allows manufacturers to apply credits

earned to any of the 3 model years prior to the model year the credits are earned, and to any of the 5 model years after the credits are earned. The transfer of credits within a manufacturer's fleet is limited to specific maximums. For model years 2011 through 2013, the maximum transfer is 1.0 mpg; for model years 2014 through 2017, the maximum transfer is 1.5 mpg; and for model years 2018 and later, the maximum credit transfer is 2.0 mpg. NEMS currently allows for sensitivity analysis of CAFE credit banking by manufacturer fleet, but does not model the trading of credits across manufacturers. The *AEO2010* does not consider trading of credits since this would require significant modifications to NEMS and detailed technology cost and efficiency data by manufacturer, which is not readily available.

The CAFE credits specified under the Alternative Motor Fuels Act (AMFA) through 2019 are extended. Prior to passage of this Act, the CAFE credits under AMFA were scheduled to expire after model year 2010. Currently, 1.2 mpg is the maximum CAFE credit that can be earned from selling alternative fueled vehicles. EISA2007 extends the 1.2 mpg credit maximum through 2014 and reduces the maximum by 0.2 mpg for each following year until it is phased out by model year 2020. NEMS does model CAFE credits earned from alternative fuel vehicles sales.

American Recovery and Reinvestment Act of 2009 and Energy Improvement and Extension Act of 2008

ARRA Title I, Section 1141 modified the EISA2008 Title II, Section 205 tax credit for the purchase of new, qualified plug-in electric drive motor vehicles. According to the legislation, a qualified plug-in electric drive motor vehicle must draw propulsion from a traction battery with at least 4 kilowatthours of capacity and is propelled to a significant extent by an electric motor which draws electricity from a battery that is capable of being recharged from an external source of electricity.

The tax credit for the purchase of a plug-in electric vehicle is \$2,500 plus, starting at a battery capacity of 5 kilowatthours, an additional \$417 per kilowatthour battery credit up to a maximum of \$7,500 per vehicle. The tax credit eligibility and phase-out are specific to an individual vehicle manufacturer. The credits are phased out once a manufacturer's cumulative sales maximum after December 31, 2009. The credit is reduced to 50 percent of the total value for the first two calendar quarters of the phase-out period and then to 25 percent for the third and fourth calendar quarters before being phased out entirely thereafter. The credit applies to vehicles with a gross vehicle weight rating of less than 14,000 pounds.

ARRA also allows a tax credit of 10 percent against the cost of a qualified electric vehicle with a battery capacity of at least 4 kilowatthours subject to the same phase out rules as above. The tax credits for qualified plug-in electric drive motor vehicles and electric vehicles are included in *AEO2010*.

Energy Policy Act of 1992 (EPACT)

Fleet alternative-fuel vehicle sales necessary to meet the EPACT regulations are derived based on the mandates as they currently stand and the Commercial Fleet Vehicle Module calculations. Total projected AFV sales are divided into fleets by government, business, and fuel providers (Table 7.10).

Because the commercial fleet model operates on three fleet type representations (business, government, and utility), the federal and state mandates are weighted by fleet vehicle stocks to create a composite mandate for both. The same combining methodology is used to create a composite mandate for electric utilities and fuel providers based on fleet vehicle stocks. [35]

Low Emission Vehicle Program (LEVP)

The LEVP was originally passed into legislation in 1990 in the State of California. It began as the implementation of a voluntary opt-in pilot program under the purview of Clean Air Act Amendments of 1990 (CAAA90), which included a provision that other States could opt in to the California program to achieve lower emissions levels than would otherwise be achieved through CAAA90. 14 states have elected to adopt the California LEVP.

The LEVP is an emissions-based policy, setting sales mandates for 6 categories of low-emission vehicles: low-emission vehicles (LEVs), ultra-low-emission vehicles (ULEVs), super-ultra low emission vehicles (SULEVs), partial zero-emission vehicles (PZEVs), advanced technology partial zero emission vehicles

Table 7.10. EPACT Legislative Mandates for AFV Purchases by Fleet Type and Year
(Percent)

Year	Federal	State	Fuel Providers	Electric Utilities
2005	75	75	70	90

Source: EIA, Energy Efficiency and Renewable Energy (Washington, DC, 2005), <http://www1.eere.energy.gov/femp/about/fleet-requirements.html>, http://www1.eere.energy.gov/vehicles_and_fuels/epact/state/state-gov.html.

(AT-PZEVs), and zero-emission vehicles (ZEVs). The LEVP requires that in 2005 10 percent of a manufacturer's sales are ZEVs or equivalent ZEV earned credits, increasing to 11 percent in 2009, 12 percent in 2012, 14 percent in 2015, and 16 percent in 2018 where it remains constant thereafter. In August 2004, CARB enacted further amendments to the LEVP that place a greater emphasis on emissions reductions from PZEVs and AT-PZEVs and requires that manufacturers produce a minimum number of fuel cell and electric vehicles. In addition, manufacturers are allowed to adopt alternative compliance requirements for ZEV sales that are based on cumulative fuel cell vehicle sales targets for vehicles sold in all States participating in California's LEVP. Under the alternative compliance requirements, ZEV credits can also be earned by selling battery electric vehicles. Currently, all manufacturers have opted to adhere to the alternative compliance requirements. The mandate still includes phase-in multipliers for pure ZEVs and allows 20 percent of the sales requirement to be met with AT-PZEVs and 60 percent of the requirement to be met with PZEVs. AT-PZEVs and PZEVs are allowed 0.2 credits per vehicle. EIA assumes that credit allowances for PZEVs will be met with conventional vehicle technology, hybrid vehicles will be sold to meet the AT-PZEV allowances, and that hydrogen fuel cell vehicles will be sold to meet the pure ZEV requirements under the alternative compliance path.

Transportation Alternative Cases

High Technology Case

In the *high technology* and *low technology* cases for cars and light trucks, the conventional fuel saving technology characteristics are based on NHTSA and EPA values. [36] Tables 7.10, 7.11, 7.12, 7.13, and 7.14 summarize the High and Low Technology matrices for cars and light trucks. Tables 7.15 and 7.16 reflect the *high* and *low technology* case assumptions for heavy trucks. These reflect optimistic and pessimistic values, with respect to efficiency improvement and capital cost, for advanced engine and emission control technologies as reported by ANL. [37]

For the Air Module, the *high technology* case reflects earlier introduction years for the new aircraft technologies and a greater penetration share. The *low technology* case is reflected by a delay in the introduction of new aircraft technologies. Tables 7.17 and 7.18 reflect these cases.

Table 7.11. High Technology Matrix For Cars

	Fractional Fuel Efficiency Change	Incremental Cost (1990\$)	Incremental Cost (\$/Unit Wt.)	Incremental Weight (Lbs.)	Incremental Weight (Lbs./Unit Wt.)	Introduction Year	Fractional Horse- power Change
Unit Body Construction	4	100	0	0	-6	1980	0
Material Substitution II	3.3	0	0.4	0	-5	1990	0
Material Substitution III	6.6	0	0.6	0	-10	1998	0
Material Substitution IV	9.9	0	0.9	0	-15	2006	0
Material Substitution V	13.2	0	1.2	0	-20	2014	0
Drag Reduction II	1.6	16	0	0	0	1988	0
Drag Reduction III	3.2	32	0	0	0.2	1992	0
Drag Reduction IV	6.3	45	0	0	0.5	2000	0
Drag Reduction V	8	53.5	0	0	1	2010	0
Roll-Over Technology	-1.5	100	0	0	2.2	2004	0
Side Impact Technology	-1.5	100	0	0	2.2	2004	0
Adv Low Loss Torque Converter	2	25	0	0	0	1999	0
Early Torque Converter Lockup	1	25.6	0	0	0	2002	0
Aggressive Shift Logic	2	30.5	0	0	0	1999	0
4-Speed Automatic	4.5	285	0	10	0	1980	0
5-Speed Automatic	8	106.5	0	20	0	1995	0
6-Speed Automatic	3.4	259	0	30	0	2003	0
6-Speed Manual	2	91.4	0	20	0	1995	0
CVT	8	240.5	0	-25	0	1998	0
Automated Manual Trans	12	120.4	0	0	0	2004	0
Roller Cam	2	16	0	0	0	1980	0
OHC/AdvOHV-4 Cylinder	3	93.1	0	0	0	1980	2.5
OHC/AdvOHV-6 Cylinder	3	108.9	0	0	0	1987	2.5
OHC/AdvOHV-8 Cylinder	3	124.7	0	0	0	1986	2.5
4-Valve/4-Cylinder	8.8	205	0	10	0	1988	4.25
4-Valve/6-Cylinder	8.8	280	0	15	0	1992	4.25
4 Valve/8-Cylinder	8.8	320	0	20	0	1994	4.25
5 Valve/6-Cylinder	9	300	0	18	0	1998	5
VVT-4 Cylinder	3	35	0	10	0	1994	1.25
VVT-6 Cylinder	3	87.5	0	20	0	1993	1.25
VVT-8 Cylinder	3	90	0	20	0	1993	1.25
VVL-4 Cylinder	3	144.3	0	25	0	1997	2.5
VVL-6 Cylinder	3	220.0	0	40	0	2000	2.5
VVL-8 Cylinder	3	285.0	0	50	0	2000	2.5
Camless Valve Actuation-4cyl	15.1	363.8	0	35	0	2020	3.25
Camless Valve Actuation-6cyl	15.1	513.0	0	55	0	2020	3.25
Camless Valve Actuation-8cyl	15.1	675.5	0	75	0	2020	3.25
Cylinder Deactivation	7.5	60.1	0	10	0	2004	0
Turbocharging/ Supercharging	7.5	324.7	0	-100	0	1980	3.75
Engine Friction Reduction I	2.3	54	0	0	0	1992	0.75
Engine Friction Reduction II	3.5	60.9	0	0	0	2000	1.75
Engine Friction Reduction III	5	52.1	0	0	0	2008	1.75
Engine Friction Reduction IV	6.5	177	0	0	0	2016	2.25
Stoichiometric GDI/4-Cylinder	2.9	234.9	0	20	0	2006	2.5
Stoichiometric GDI/6-Cylinder	2.9	307.9	0	30	0	2006	2.5
Lean Burn GDI	10	640.5	0	20	0	2020	0
5W-30 Engine Oil	1	3	0	0	0	1998	0
5W-20 Engine Oil	2	16.7	0	0	0	2003	0
OW-20 Engine Oil	3.1	150	0	0	0	2030	0
Electric Power Steering	2	84.2	0	0	0	2004	0
Improved Alternator	0.3	15	0	0	0	2005	0
Improved Oil/Water Pump	0.5	10	0	0	0	2000	0
Electric Oil/Water Pump	1	93.4	0	0	0	2007	0
Tires II	2	6.1	0	-8	0	1995	0
Tires III	3.5	12.3	0	-12	0	2005	0
Tires IV	5	16.9	0	-16	0	2015	0
Front Wheel Drive	6	250	0	0	-6	1980	0
Four Wheel Drive Improvements	2	93.8	0	0	-1	2000	0
42V-Launch Assist and Regen	7.5	280	0	80	0	2005	-2.5
42V-Engine Off at Idle	7.5	496.6	0	45	0	2005	0
Tier 2 Emissions Technology	-1	120	0	20	0	2006	0
Increased Size/Weight	-1.7	0	0	0	2.55	2003	0
Variable Compression Ratio	4	350	0	25	0	2015	0

Source: Energy and Environmental Analysis, *Documentation of Technology included in the NEMS Fuel Economy Model for Passenger Cars and Light Trucks* (September, 2002). National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards* (Copyright 2002). National Highway Traffic Safety Administration, *Corporate Average Fuel Economy for MY 2011-2015 Passenger Cars and Light Trucks* (April 2008). U.S. Environmental Protection Agency, *Interim Report: New Powertrain Technologies and Their Projected Costs* (October 2005)

Table 7.12. High Technology Matrix For Light Trucks

	Fractional Fuel Efficiency Change	Incremental Cost (1990\$)	Incremental Cost (\$/Unit Wt.)	Incremental Weight (Lbs.)	Incremental Weight (Lbs./Unit Wt.)	Introduction Year	Fractional Horse- power Change
Unit Body Construction	4	100	0	0	-6	1980	0
Material Substitution II	3.3	0	0.4	0	-5	1994	0
Material Substitution III	6.6	0	0.6	0	-10	2002	0
Material Substitution IV	9.9	0	0.9	0	-15	2010	0
Material Substitution V	13.2	0	1.2	0	-20	2018	0
Drag Reduction II	2.3	32	0	0	0	1992	0
Drag Reduction III	4.1	57	0	0	0.2	1998	0
Drag Reduction IV	6.4	89	0	0	0.5	2006	0
Drag Reduction V	7.8	109	0	0	1	2014	0
Roll-Over Technology	-1.5	100	0	0	2.2	2006	0
Side Impact Technology	-1.5	100	0	0	2.2	2006	0
Adv Low Loss Torque Converter	2	25	0	0	0	2005	0
Early Torque Converter Lockup	0.5	25.6	0	0	0	2003	0
Aggressive Shift Logic	2.0	35	0	0	0	1999	0
4-Speed Automatic	4.5	285	0	10	0	1980	0
5-Speed Automatic	8	106.5	0	20	0	1995	0
6-Speed Automatic	3.4	259	0	30	0	2003	0
6-Speed Manual	2	91.4	0	20	0	1995	0
CVT	8	130.0	0	-25	0	1998	0
Automated Manual Trans	3.4	120.4	0	0	0	2004	0
Roller Cam	2	16	0	0	0	1985	0
OHC/AdvOHV-4 Cylinder	3.5	93.1	0	0	0	1980	2.5
OHC/AdvOHV-6 Cylinder	3.5	108.9	0	0	0	1990	2.5
OHC/AdvOHV-8 Cylinder	3.5	124.7	0	0	0	1990	4.25
4-Valve/4-Cylinder	7.0	205	0	10	0	1998	4.25
4-Valve/6-Cylinder	7.0	280	0	15	0	2000	4.25
4 Valve/8-Cylinder	7.0	320	0	20	0	2000	4.25
5 Valve/6-Cylinder	7.0	300	0	18	0	2010	5
VVT-4 Cylinder	3	48.9	0	10	0	1998	1.25
VVT-6 Cylinder	3	97.8	0	20	0	1997	1.25
VVT-8 Cylinder	3	97.8	0	20	0	1997	1.25
VVL-4 Cylinder	3	144.3	0	25	0	2002	2.5
VVL-6 Cylinder	3	220	0	40	0	2001	2.5
VVL-8 Cylinder	3	285	0	50	0	2006	2.5
Camless Valve Actuation-4cyl	15.1	363.8	0	35	0	2020	3.25
Camless Valve Actuation-6cyl	15.1	513	0	55	0	2020	3.25
Camless Valve Actuation-8cyl	15.1	657.5	0	75	0	2020	3.25
Cylinder Deactivation	7.5	60.1	0	10	0	2004	0
Turbocharging/Supercharging	7.5	339	0	-100	0	1987	3.75
Engine Friction Reduction I	2.5	25	0	0	0	1992	0.75
Engine Friction Reduction II	3.5	31.2	0	0	0	2000	1.25
Engine Friction Reduction III	5	62.5	0	0	0	2010	1.75
Engine Friction Reduction IV	6.5	67.5	0	0	0	2016	2.75
Stoichiometric GDI/4-Cylinder	2.9	234.9	0	20	0	2008	2.5
Stoichiometric GDI/6-Cylinder	2.9	307.9	0	30	0	2010	2.5
Lean Burn GDI	11.5	640.5	0	20	0	2010	0
5W-30 Engine Oil	0.8	4	0	0	0	1998	0
5W-20 Engine Oil	2	16.7	0	0	0	2003	0
OW-20 Engine Oil	3.1	150	0	0	0	2030	0
Electric Power Steering	2	84.2	0	0	0	2005	0
Improved Alternator	0.3	15	0	0	0	2005	0
Improved Oil/Water Pump	0.5	10	0	0	0	2000	0
Electric Oil/Water Pump	1	93.4	0	0	0	2008	0
Tires II	0.0	30	0	-8	0	1995	0
Tires III	1.5	5.6	0	-12	0	2005	0
Tires IV	3.5	11.8	0	-16	0	2015	0
Front Wheel Drive	2	250	0	0	-3	1984	0
Four Wheel Drive Improvements	1.5	93.8	0	0	-1	2000	0
42V-Launch Assist and Regen	7.5	280	0	80	0	2005	-2.5
42V-Engine Off at Idle	7.5	434.9	0	45	0	2005	0
Tier 2 Emissions Technology	-1	160	0	20	0	2006	0
Increased Size/Weight	-2.5	0	0	0	3.75	2006	0
Variable Compression Ratio	4	350	0	25	0	2015	0

Source: Energy and Environmental Analysis, *Documentation of Technology included in the NEMS Fuel Economy Model for Passenger Cars and Light Trucks* (September, 2002). National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards* (Copyright 2002). National Highway Traffic Safety Administration, *Corporate Average Fuel Economy for MY 2011-2015 Passenger Cars and Light Trucks* (April 2008). U.S. Environmental Protection Agency, *Interim Report: New Powertrain Technologies and Their Projected Costs* (October 2005)

Table 7.13. Low Technology Matrix For Cars¹

	Fractional Fuel Efficiency Change	Incremental Cost (1990\$)	Incremental Cost (\$/Unit Wt.)	Incremental Weight (Lbs.)	Incremental Weight (Lbs./Unit Wt.)	Introduction Year	Fractional Horse-power Change
Unit Body Construction	4	100	0	0	-6	1980	0
Material Substitution II	3.3	0	0.4	0	-5	1990	0
Material Substitution III	6.6	0	0.6	0	-10	1998	0
Material Substitution IV	9.9	0	0.9	0	-15	2006	0
Material Substitution V	13.2	0	1.2	0	-20	2014	0
Drag Reduction II	1.5	16.0	0	0	0	1988	0
Drag Reduction III	3.0	32.0	0	0	0.2	1992	0
Drag Reduction IV	4.2	45.0	0	0	0.5	2000	0
Drag Reduction V	5.0	53.5	0	0	1	2010	0
Roll-Over Technology	-1.5	100	0	0	2.2	2004	0
Side Impact Technology	-1.5	100	0	0	2.2	2004	0
Adv Low Loss Torque Converter	2	25	0	0	0	1999	0
Early Torque Converter Lockup	0.5	25.6	0	0	0	2002	0
Aggressive Shift Logic	1.0	30.5	0	0	0	1999	0
4-Speed Automatic	4.5	285	0	10	0	1980	0
5-Speed Automatic	2.5	106.5	0	20	0	1995	0
6-Speed Automatic	2	259	0	30	0	2003	0
6-Speed Manual	0.5	91.4	0	20	0	1995	0
CVT	2	240.5	0	-25	0	1998	0
Automated Manual Trans	4.0	175.0	0	0	0	2004	0
Roller Cam	2	16	0	0	0	1980	0
OHC/AdvOHV-4 Cylinder	3.5	105.0	0	0	0	1980	2.5
OHC/AdvOHV-6 Cylinder	1.5	122.5	0	0	0	1987	2.5
OHC/AdvOHV-8 Cylinder	1.5	140.0	0	0	0	1986	2.5
4-Valve/4-Cylinder	8	205	0	10	0	1988	4.25
4-Valve/6-Cylinder	8	280	0	15	0	1992	4.25
4 Valve/8-Cylinder	8	320	0	20	0	1994	4.25
5 Valve/6-Cylinder	8	300	0	18	0	1998	5
VVT-4 Cylinder	1.0	50.4	0	10	0	1994	1.25
VVT-6 Cylinder	1.0	114.4	0	20	0	1993	1.25
VVT-8 Cylinder	1.0	178.5	0	20	0	1993	1.25
VVL-4 Cylinder	2.0	178	0	25	0	1997	2.5
VVL-6 Cylinder	2.0	270	0	40	0	2000	2.5
VVL-8 Cylinder	2.0	349	0	50	0	2000	2.5
Camless Valve Actuation-4cyl	12.1	433	0	35	0	2020	3.25
Camless Valve Actuation-6cyl	12.1	609.4	0	55	0	2020	3.25
Camless Valve Actuation-8cyl	12.1	785.8	0	75	0	2020	3.25
Cylinder Deactivation	4.0	245	0	10	0	2004	0
Turbocharging/Supercharging	5.0	324.7	0	-100	0	1980	3.75
Engine Friction Reduction I	2.3	54	0	0	0	1992	0.75
Engine Friction Reduction II	2.0	60.9	0	0	0	2000	1.25
Engine Friction Reduction III	3.0	196.4	0	0	0	2008	1.75
Engine Friction Reduction IV	6.5	177	0	0	0	2016	2.25
Stoichiometric GDI/4-Cylinder	1.9	352	0	20	0	2006	2.5
Stoichiometric GDI/6-Cylinder	1.9	447.0	0	30	0	2006	2.5
Lean Burn GDI	10.0	640.5	0	20	0	2020	0
5W-30 Engine Oil	0.5	6.0	0	0	0	1998	0
5W-20 Engine Oil	2	16.7	0	0	0	2003	0
OW-20 Engine Oil	3.1	150	0	0	0	2030	0
Electric Power Steering	1.0	96.2	0	0	0	2004	0
Improved Alternator	0.3	15	0	0	0	2005	0
Improved Oil/Water Pump	0.5	10	0	0	0	2000	0
Electric Oil/Water Pump	1	93.4	0	0	0	2007	0
Tires II	1.5	35	0	-8	0	1995	0
Tires III	1.5	35	0	-12	0	2005	0
Tires IV	1.5	35	0	-16	0	2015	0
Front Wheel Drive	6	250	0	0	-6	1980	0
Four Wheel Drive Improvements	1.3	93.8	0	0	-1	2000	0
42V-Launch Assist and Regen	7.5	280	0	80	0	2005	-2.5
42V-Engine Off at Idle	5.5	496.6	0	45	0	2005	0
Tier 2 Emissions Technology	-1	120	0	20	0	2006	0
Increased Size/Weight	-1.7	0	0	0	2.55	2006	0
Variable Compression Ratio	4	350	0	25	0	2015	0

¹ Fractional changes refer to the percentage change from the 1990 values.

Sources: Energy and Environment Analysis, *Documentation of Technology included in the NEMS Fuel Economy Model for Passenger Cars and Light Trucks* (September, 2002). National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards* (Copyright 2002). National Highway Traffic Safety Administration, *Corporate Average Fuel Economy for MY 2011-2015 Passenger Cars and Light Trucks* (April 2008). U.S. Environmental Protection Agency, *Interim Report: New Powertrain Technologies and Their Projected Costs* (October 2005)

Table 7.14. Low Technology Matrix For Light Trucks¹

	Fractional Fuel Efficiency Change	Incremental Cost (1990\$)	Incremental Cost (\$/UnitWt.)	Incremental Weight Weight (Lbs.)	Incremental Weight (Lbs./UnitWt.)	Introduction Year	Fractional Horse- power Change
Unit Body Construction	4	100	0	0	-6	1980	0
Material Substitution II	3.3	0	0.4	0	-5	1994	0
Material Substitution III	6.6	0	0.6	0	-10	2002	0
Material Substitution IV	9.9	0	0.9	0	-15	2010	0
Material Substitution V	13.2	0	1.2	0	-20	2018	0
Drag Reduction II	1.5	32	0	0	0	1992	0
Drag Reduction III	4.1	57	0	0	0.2	1998	0
Drag Reduction IV	6.4	89	0	0	0.5	2006	0
Drag Reduction V	7.8	109	0	0	1	2014	0
Roll-Over Technology	-1.5	100	0	0	2.2	2006	0
Side Impact Technology	-1.5	100	0	0	2.2	2006	0
Adv Low Loss Torque Converter	2	25	0	0	0	2005	0
Early Torque Converter Lockup	0.5	25.6	0	0	0	2003	0
Aggressive Shift Logic	1.5	30.5	0	0	0	1999	0
4-Speed Automatic	4.5	285	0	10	0	1980	0
5-Speed Automatic	2.5	112	0	20	0	1995	0
6-Speed Automatic	2.0	259.0	0	30	0	2003	0
6-Speed Manual	0.5	91.4	0	20	0	1995	0
CVT	3.0	200	0	-25	0	1998	0
Automated Manual Trans	3.4	157.5	0	0	0	2004	0
Roller Cam	2	16	0	0	0	1985	0
OHC/AdvOHV-4 Cylinder	1.8	105	0	0	0	1980	2.5
OHC/AdvOHV-6 Cylinder	1.8	122.5	0	0	0	1990	2.5
OHC/AdvOHV-8 Cylinder	1.8	140	0	0	0	1990	2.5
4-Valve/4-Cylinder	7	205	0	10	0	1998	4.25
4-Valve/6-Cylinder	7	280	0	15	0	2000	4.25
4 Valve/8-Cylinder	7	320	0	20	0	2000	4.25
5 Valve/6-Cylinder	7	300	0	18	0	2010	5
VVT-4 Cylinder	1.0	48.9	0	10	0	1998	1.25
VVT-6 Cylinder	1.0	97.8	0	20	0	1997	1.25
VVT-8 Cylinder	1.0	97.8	0	20	0	1997	1.25
VVL-4 Cylinder	2.0	178	0	25	0	2002	2.5
VVL-6 Cylinder	2.0	270	0	40	0	2001	2.5
VVL-8 Cylinder	2.0	349	0	50	0	2006	2.5
Camless Valve Actuation-4cyl	12.1	433	0	35	0	2020	3.25
Camless Valve Actuation-6cyl	12.1	609.4	0	55	0	2020	3.25
Camless Valve Actuation-8cyl	12.1	785.8	0	75	0	2020	3.25
Cylinder Deactivation	4.0	190.4	0	10	0	2004	0
Turbocharging/Supercharging	5.0	650	0	-100	0	1987	3.75
Engine Friction Reduction I	2.0	36	0	0	0	1992	0.75
Engine Friction Reduction II	1.5	63	0	0	0	2000	1.25
Engine Friction Reduction III	1.5	235.7	0	0	0	2010	1.75
Engine Friction Reduction IV	1.5	177	0	0	0	2016	2.25
Stoichiometric GDI/4-Cylinder	1.9	352.8	0	20	0	2008	2.5
Stoichiometric GDI/6-Cylinder	1.9	447.4	0	30	0	2010	2.5
Lean Burn GDI	10.0	640.5	0	20	0	2010	0
5W-30 Engine Oil	0.5	6.0	0	0	0	1998	0
5W-20 Engine Oil	1.0	37.5	0	0	0	2003	0
OW-20 Engine Oil	3.1	150	0	0	0	2030	0
Electric Power Steering	1.0	96.2	0	0	0	2005	0
Improved Alternator	0.3	15	0	0	0	2005	0
Improved Oil/Water Pump	0.5	10	0	0	0	2000	0
Electric Oil/Water Pump	1	93.4	0	0	0	2008	0
Tires II	0.0	30	0	-8	0	1995	0
Tires III	1.0	35	0	-12	0	2005	0
Tires IV	1.0	35	0	-16	0	2015	0
Front Wheel Drive	2	250	0	0	-3	1984	0
Four Wheel Drive Improvements	1.0	93.8	0	0	-1	2000	0
42V-Launch Assist and Regen	7.5	280	0	80	0	2005	-2.5
42V-Engine Off at Idle	5.5	434.9	0	45	0	2005	0
Tier 2 Emissions Technology	-1	160	0	20	0	2006	0
Increased Size/Weight	-2.5	0	0	0	3.75	2006	0
Variable Compression Ratio	4	350	0	25	0	2015	0

¹Fractional changes refer to the percentage change from the 1990 values.

Sources: Energy and Environment Analysis, *Documentation of Technology included in the NEMS Fuel Economy Model for Passenger Cars and Light Trucks* (September, 2002). National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards* (Copyright 2002). National Highway Traffic Safety Administration, *Corporate Average Fuel Economy for MY 2011-2015 Passenger Cars and Light Trucks* (April 2008). U.S. Environmental Protection Agency, *Interim Report: New Powertrain Technologies and Their Projected Costs* (October 2005)

Table 7.15. High Technology Matrix for Freight Trucks

Technology Type	Medium Light Trucks			Medium Heavy Trucks			Heavy Trucks		
	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement
Aero dynamic I: Cab top deflector, sloping hood and cab side flares	2002	600.00	0.028	1995	750.00	0.028	1995	750.00	0.028
Closing/covering of gap between tractor and trailer, aero dynamic bumper, underside air baffles, wheel well covers	N/A	N/A	0.000	2004	800.00	0.041	2005	1500.00	0.023
Trailer leading and trailing edge curvatures	N/A	N/A	0.000	2005	400.00	0.013	2005	500.00	0.016
Aero Dynamics IV: pneumatic blowing	N/A	N/A	0.000	N/A	N/A	0.000	2010	2500.00	0.060
Tires I: radials	1995	40.00	0.028	1995	180.00	0.028	1995	300.00	0.024
Tires II: low rolling resistance	2004	180.00	0.033	2005	280.00	0.033	2005	550.00	0.037
Tires III: super singles	N/A	N/A	0.000	N/A	N/A	0.000	2005	700.00	0.028
Tires IV: reduced rolling resistance from pneumatic blowing	N/A	N/A	0.000	N/A	N/A	0.000	2015	500.00	0.011
Transmission: lock-up, electronic controls, reduced friction	2005	750.00	0.023	2005	900.00	0.023	2005	1000.00	0.023
Diesel Engine I: turbo-charged, direct injection with better thermal management	2003	600.00	0.045	2004	900.00	0.072	N/A	N/A	0.000
Diesel Engine II: integrated starter/alternator with idle off and limited regenerative braking	2005	1500.00	0.045	2005	1200.00	0.045	N/A	N/A	0.000
Diesel Engine III: improved engine with lower friction, better injectors, and efficient combustion	2012	2000.00	0.080	2008	2000.00	0.082	N/A	300.00	0.000
Diesel Engine IV: hybrid electric powertrain	2010	6000.00	0.360	2010	7000.00	0.360	N/A	N/A	0.000
Diesel Engine V: internal friction reduction - improved lubricants and bearings	N/A	N/A	0.000	N/A	N/A	0.000	2005	500.00	0.018
Diesel Engine VI: increased peak cylinder pressure	N/A	NA	0.000	N/A	N/A	0.000	2006	1000.00	0.036
Diesel Engine VII: improved injectors and more efficient combustion	N/A	N/A	0.000	N/A	N/A	0.000	2007	1500	0.054
Diesel Engine VIII: reduce waste heat improved thermal management	N/A	N/A	0.000	N/A	N/A	0.000	2010	2000	0.090
Diesel Engine VIII: reduce waste heat and improve thermal management	N/A	N/A	0.000	N/A	N/A	0.000	2010	N/A	0.100
Gasoline Engine I: electronic fuel injection, DOHC, multiple valves	2003	700.00	0.045	2003	1000.00	0.045	N/A	N/A	0.000

Table 7.15. High Technology Matrix for Freight Trucks (cont.)

Technology Type	Medium Light Trucks			Medium Heavy Trucks			Heavy Trucks		
	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement
Gasoline Engine II: integrated starter/alternator with idle off and limited regenerative braking	2005	1000.00	0.045	2005	1200.00	0.072	N/A	N/A	0.000
Gasoline Engine III: direct injection (GDI)	2008	700.00	0.108	2008	1000.00	0.108	N/A	N/A	0.000
Gasoline Engine IV: hybrid electric powertrain	2010	6000.00	0.405	2010	8000.00	0.405	N/A	N/A	0.000
Weight Reduction I: high strength lightweight materials	2010	1300.00	0.045	2007	2000.00	0.045	2005	2000.00	0.090
Diesel Emission-NO _x I: exhaust recirculation, timing retard, selective catalytic reduction	2002	250.00	-0.030	2003	400.00	-0.030	2003	500.00	-0.030
Diesel Emissions-NO _x II: nitrogen enriched combustion air	2003	500.00	-0.005	2003	700.00	-0.005	2003	750.00	-0.005
Diesel Emissions-NO _x III: non-thermal plasma catalyst	2007	1000.00	-0.010	2006	1200.00	-0.010	2007	1250.00	-0.010
Diesel Emissions-NO _x IV: NO _x absorber system	2007	1500.00	-0.020	2006	2000.00	-0.020	2007	2500.00	-0.020
Diesel Emission-PM I: oxidation catalyst	2002	150.00	-0.005	2002	200.00	-0.005	2002	250.00	-0.005
Diesel Emission-PM II: catalytic particulate filter	2006	1000.00	-0.010	2006	1250.00	-0.020	2006	1500.00	-0.010
Diesel Emission-HC/CO I: oxidation catalyst	2002	150.00	-0.005	2002	200.00	-0.005	2002	250.00	-0.005
Diesel Emission-HC/CO II: closed crankcase system	2005	50.00	0.000	2005	65.00	0.000	2005	75.00	0.000
Gasoline Emission-PM I: Improved oxidation catalyst	2005	250.00	-0.003	2005	350.00	-0.003	N/A	N/A	0.000
Gasoline Emission-NO _x I: EGR/spark retard	2002	25.00	-0.010	2002	25.00	-0.010	N/A	N/A	0.000
Gasoline Emission-NO _x II: oxygen sensors	2003	75.00	0.000	2003	75.00	0.000	N/A	N/A	0.000
Gasoline Emission-NO _x III: secondary air/closed loop system	2008	50.00	0.000	2008	50.00	0.000	N/A	N/A	0.000
Gasoline Emission-HC/CO I: oxygen sensors	2003	75.00	0.000	2003	75.00	0.000	N/A	N/A	0.000

Table 7.15. High Technology Matrix for Freight Trucks (cont.)

Technology Type	Medium Light Trucks			Medium Heavy Trucks			Heavy Trucks		
	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement
Gasoline Emission-HC/CO II: evap. canister w/improved vacuum, materials, and connectors	2003	50.00	0.000	2003	50.00	0.000	N/A	N/A	0.000
Gasoline Emission-HC/CO III: oxidation catalyst	2005	250.00	-0.003	2005	350.00	-0.003	N/A	N/A	0.000

1. Payback period is same for the three modes.

Table 7.16. Low Technology Matrix for Freight Trucks

Technology Type	Medium Light Trucks			Medium Heavy Trucks			Heavy Trucks		
	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement
Aero dynamic I: Cab top deflector, sloping hood and cab side flares	2002	600.00	0.018	1995	750.00	0.018	1995	750.00	0.013
Closing/covering of gap between tractor and trailer, aero dynamic bumper, underside air baffles, wheel well covers	N/A	N/A	0.000	2004	800.00	0.031	2005	1500.00	0.023
Trailer leading and trailing edge curvatures	N/A	N/A	0.000	2005	400.00	0.005	2005	500.00	0.008
Aero Dynamics IV: pneumatic blowing	N/A	N/A	0.000	N/A	N/A	0.000	2010	2500.00	0.030
Tires I: radials	1995	40.00	0.008	1995	180.00	0.008	1995	300.00	0.004
Tires II: low rolling resistance	2004	180.00	0.013	2005	280.00	0.033	2005	550.00	0.017
Tires III: super singles	N/A	N/A	0.000	N/A	N/A	0.000	2005	700.00	0.008
Tires IV: reduced rolling resistance from pneumatic blowing	N/A	N/A	0.000	N/A	N/A	0.000	2015	500.00	0.011
Transmission: lock-up, electronic controls, reduced friction	2005	750.00	0.013	2005	900.00	0.013	2005	1000.00	0.013
Diesel Engine I: turbo-charged, direct injection with better thermal management	2003	800.00	0.045	2004	1100.00	0.072	N/A	N/A	0.000
Diesel Engine II: integrated starter/alternator with idle off and limited regenerative braking	2005	1500.00	0.045	2005	1200.00	0.045	N/A	N/A	0.000
Diesel Engine III: improved engine with lower friction, better injectors, and efficient combustion	2012	2000.00	0.070	2008	2000.00	0.062	N/A	300.00	0.000
Diesel Engine IV: hybrid electric powertrain	2010	6000.00	0.360	2010	9000.00	0.360	N/A	N/A	0.000
Diesel Engine V: internal friction reduction - improved lubricants and bearings	N/A	N/A	0.000	N/A	N/A	0.000	2005	500.00	0.018
Diesel Engine VI: increased peak cylinder pressure	N/A	N/A	0.000	N/A	N/A	0.000	2006	1000.00	0.036
Diesel Engine VII: improved injectors and more efficient combustion	N/A	N/A	0.000	N/A	N/A	0.000	2007	1500	0.054
Diesel Engine VIII: reduce waste heat improved thermal management	N/A	N/A	0.000	N/A	N/A	0.000	2010	2000	0.090
Diesel Engine VIII: reduce waste heat and improve thermal management	N/A	N/A	0.000	N/A	N/A	0.000	2010	N/A	0.100

Table 7.16. Low Technology Matrix for Freight Trucks (cont.)

Technology Type	Medium Light Trucks			Medium Heavy Trucks			Heavy Trucks		
	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement
Gasoline Engine I: electronic fuel injection, DOHC, multiple valves	2003	700.00	0.045	2003	1000.00	0.045	N/A	N/A	0.000
Gasoline Engine II: integrated starter/ alternator with idle off and limited regenerative braking	2005	1000.00	0.045	2005	1200.00	0.072	N/A	N/A	0.000
Gasoline Engine III: direct injection (GDI)	2008	700.00	0.108	2008	1000.00	0.108	N/A	N/A	0.000
Gasoline Engine IV; hybrid electric powertrain	2010	6000.00	0.405	2010	8000.00	0.405	N/A	N/A	0.000
Weight Reduction I: high strength lightweight materials	2010	1300.00	0.045	2007	2000.00	0.045	2005	2000.00	0.090
Diesel Emission-NO _x I: exhaust recirculation, timing retard, selective catalytic reduction	2002	250.00	-0.050	2003	400.00	-0.050	2003	500.00	-0.050
Diesel Emissions-NO _x II: nitrogen enriched combustion air	2003	500.00	-0.005	2003	700.00	-0.005	2003	750.00	-0.005
Diesel Emissions-NO _x III: non-thermal plasma catalyst	2007	1000.00	-0.020	2006	1200.00	-0.020	2007	1250.00	-0.020
Diesel Emissions-NO _x IV: NO _x absorber system	2007	1500.00	-0.040	2006	2000.00	-0.040	2007	2500.00	-0.040
Diesel Emission-PM I: oxidation catalyst	2002	150.00	-0.005	2002	200.00	-0.005	2002	250.00	-0.005
Diesel Emission-PM II: catalytic particulate filter	2006	1000.00	-0.020	2006	1250.00	-0.030	2006	1500.00	-0.020
Diesel Emission-HC/CO I: oxidation catalyst	2002	150.00	-0.005	2002	200.00	-0.005	2002	250.00	-0.005
Diesel Emission- HC/CO II: closed crankcase system	2005	50.00	0.000	2005	65.00	0.000	2005	75.00	0.000
Gasoline Emission- PM I: Improved oxidation catalyst	2005	250.00	-0.003	2005	350.00	-0.003	N/A	N/A	0.000
Gasoline Emission-NO _x I: EGR/spark retard	2002	25.00	-0.020	2002	25.00	-0.020	N/A	N/A	0.000
Gasoline Emission-NO _x II: oxygen sensors	2003	75.00	0.000	2003	75.00	0.000	N/A	N/A	0.000
Gasoline Emission-NO _x III: secondary air/closed loop system	2008	50.00	0.000	2008	50.00	0.000	N/A	N/A	0.000

Table 7.16. Low Technology Matrix for Freight Trucks (cont.)

Technology Type	Medium Light Trucks			Medium Heavy Trucks			Heavy Trucks		
	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement	Introduction Year	Capital Cost	Incr. Fuel Econ. Improvement
Gasoline Emission-HC/CO I: oxygen sensors	2003	75.00	0.000	2003	75.00	0.000	N/A	N/A	0.000
Gasoline Emission-HC/CO II: evap. canister w/improved vacuum, materials, and connectors	2003	50.00	0.000	2003	50.00	0.000	N/A	N/A	0.000
Gasoline Emission-HC/CO III: oxidation catalyst	2005	250.00	-0.003	2005	350.00	-0.003	N/A	N/A	0.000

1. Payback period is same for the three modes.

Table 7.17. High Technology Matrix for Air Travel

Technology	Introduction Year	Fractional Efficiency Improvement	Jet Fuel Trigger Price (\$/gal)
Technology #1	2008	0.03	1.34
Technology #2	2009	0.07	1.34
Technology #3	2015	0.11	1.34
Technology #4	2020	0.15	1.34
Technology #5	2018	0.22	1.34
Technology #6	2018	0.10	1.34
Technology #7	2025	0.00	1.00
Technology #8	2020	0.10	0.00
Technology #9	9999	0.00	0.00

Source: Jet Information Services, 2008 World Jet Inventory, data tables (2008). Energy Information Administration, *Transportation Sector Model of the National Energy Modeling System, Model Documentation 2008*, DOE/EIA-M070(2008), (Washington, DC, 2008).

Table 7.18. Low Technology Matrix for Air Travel

Technology	Introduction Year	Fractional Efficiency Improvement	Jet Fuel Trigger Price (\$/gal)
Technology #1	2008	0.03	1.34
Technology #2	2019	0.07	1.34
Technology #3	2025	0.11	1.34
Technology #4	9999	0.00	1.34
Technology #5	2018	0.10	1.34
Technology #6	2018	0.10	1.34
Technology #7	9999	0.00	1.00
Technology #8	9999	0.00	0.00
Technology #9	9999	0.00	0.00

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